[From the American Journal of Science, Vol. II, December, 1896.]

THE JURASSIC FORMATION ON THE ATLANTIC COAST.

By O. C. Marsh.

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The absence of all Jurassic strata in the eastern part of the United States has been generally regarded as a settled point in geology for half a century or more. The reason for this vacancy has also been one of the problems geologists have had to deal with, since the formations above and below are well represented. Until a comparatively modern date, this supposed absence of Jurassic deposits was thought to be true, also, for the rest of this country. I well remember the parting advice given me by an eminent professor of geology with whom I studied in Germany.† "The first thing you should do on your return to America is,—look for the Jurassic formation. I am sure it is there, full of fossils." This advice I followed, and on my first visit to the Rocky Mountains, in 1868, I found this formation near Lake Como, Wyoming, well developed, and containing an abundance of typical fossils. As this locality is now a famous one, I have brought here a colored drawing that shows the characteristic varicgated strata of the Como Bluff, from which so many remains of Jurassic vertebrates have been taken during my long explorations there.

The base of this section is a red sandstone, apparently of Triassic age. Next above are Jurassic marine beds, with many invertebrate fossils and a few remains of reptiles. Over these beds is a series of peculiar, highly colored clays of fresh-water origin and considerable thickness, rich in vertebrate fossils. Crowning all is the characteristic Dakota sandstone, generally considered of Cretaceous age. The position of this series of strata in the geological scale is shown in the section below, which represents especially the succession of vertebrate life in the West during Mesozoic and Cenozoic time.

The Baptanodon Beds.

The same marine beds that constitute the base of the Como Jurassic series, Meek had previously identified near the Black Hills, by means of invertebrate fossils (Proc. Acad. Nat. Sci., Phila., vol. x, pp. 41–59, 1859). I found these deposits again in 1870, near the Green River in Utah, and since then at various other points. These strata I have named the Baptanodon beds, from a genus of large swimming reptiles entombed in them.

* Abstract of Communication made to the National Academy of Sciences, New York meeting, November 18, 1896.

† Ferdinand Roemer, whose researches here had already added much to our knowledge of the geology and paleontology of this country.

The Atlantosaurus Beds.

The extensive fresh-water deposits of Jurassic age, that lie over the marine strata at Como, I have called the Atlantosaurus beds, from a gigantic Dinosaur especially characteristic of the horizon. Other Dinosaurs, large and small, and a great number and variety of vertebrate fossils,—mammals, birds, reptiles,

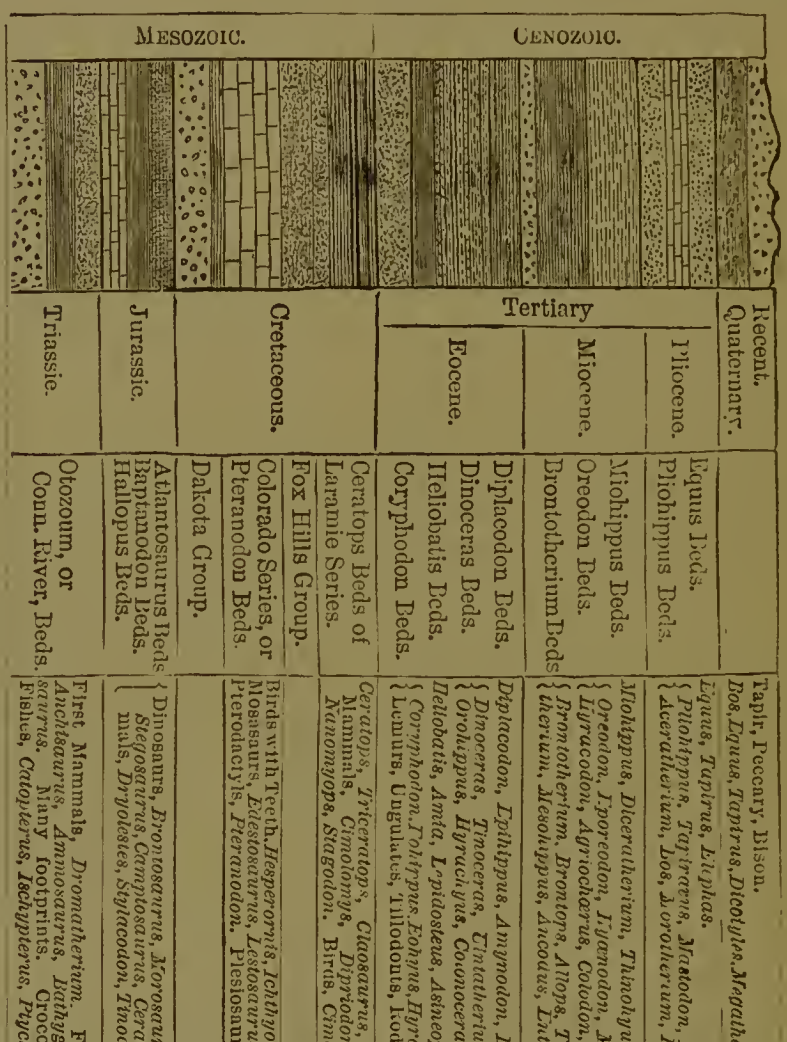

FIGURE 1.—GEOLOGICAL HORIZONS OF VERTEBRATE FOSSILS.

and fishes, I have likewise secured from this locality and at several other points in the same horizon, chiefly in Wyoming and Colorado. Among these extinct forms, the gigantic *Sauropoda*, the largest of all land animals, are the most wonderful, and are known only from the Jurassic. They are therefore of special value as evidence of geological age.

The main physical features of the Jurassic strata in the West, especially the variegated fresh-water deposits, are so striking that, once seen, they will not soon be forgotten. As these physical characters may be used as one means of readily identifying this horizon, I have brought here, besides the colored drawing of the Como section in Wyoming, two others illustrating sections in Colorado. One is from Morrison, near Denver, and the other one hundred miles further south, near Cañon City, both representing, in the Atlantosaurus beds, localities famous for the vertebrate fossils they have furnished. I know of no other geological horizon in the West marked by such striking and characteristic physical features.

The Pleurocœlus Beds.

In the East, the strata most resembling the Atlantosaurus beds in physical characters are the Potomac clays and sands so conspicuous between Washington and Baltimore, and known to extend, also, both to the north and south. Although fifteen hundred miles to the eastward, these Maryland strata so strongly recalled those I had explored at the base of the Rocky Mountains, I felt reasonably sure, even before I had examined them, that this series would turn out to be essentially the same age as the Atlantosaurus beds of the West. This proved to be the case. Although the Potomac beds have been generally regarded as Cretaceous, I can now safely say that the vertebrate fossils I have secured from them, especially the *Sauropoda*, demonstrate their Jurassic age beyond reasonable doubt. I stated this conclusion in my first description of Potomac fossils, and it is now fully confirmed by more recent discoveries.*

The fact that the *Sauropoda* of the Potomac beds are all of diminutive size, in comparison with the western forms, is a point of some importance in estimating the age of the strata that contain them. It is a rule almost without exception, that the earlier members of an order of ancient vertebrate animals are small, while the last survivors before extinction are the largest. The gigantic forms of every such group left no successors. Hence, the small *Pleurocœlidæ* of the East may possibly be the ancestors of the huge western *Atlantosauridæ*, but can hardly be their descendants. The other vertebrate fossils from the Potomac of Maryland, although fragmentary, all appear to be Jurassic in type.

* This Journal, vol. xxxv, p. 90, 1888. See also, Sixteenth Annual Report, U. S. Geol. Survey, Part I, p. 183, 1896.

It cannot, of course, be positively asserted at present that the entire series now known as Potomac is all Jurassic, or represents the whole Jurassic. The Lias appears to be wanting, and some of the upper strata may possibly prove to belong to the Dakota.

The latter formation in the West often lies apparently conformably on the Atlantosaurus beds, and besides its many fossil plants contains fragments of bones, but these may have washed out of the Jurassic clays below. Footprints resembling those of birds have also been found.

The Potomac Formation.

The Maryland Potomac, as we know it to-day, is the keystone to the arch. If this is Jurassic, as now seems certain, it is a fair conclusion that the same series of deposits, north and south, are essentially of the same age. The only region along this line of a thousand miles or more, where a systematic search for vertebrate fossils has been made, is in Maryland, and here a rich fauna has been found. Doubtless in many outcrops of this formation, animal remains may be rare or absent, as they appear to be in the Triassic below, but vertebrate life we know was abundant during the Jurassic, and characteristic remains will sooner or later come to light.

Taking, then, the Potomac formation as it is developed in Maryland as an eastern representative of the Jurassic, let us see what follows. The authorities on this formation—McGee, Ward, Fontaine, Uhler, and others, agree that it extends south along the Atlantic border as far as North Carolina, holding the same relative position, and the same general characteristics. That it also extends west around the Gulf border has been asserted by those most familiar with its southern development, but on this point I cannot speak from personal observation.

From the Potomac River northward, however, I have made sufficient explorations along its outcrops through Maryland, Delaware, and Pennsylvania, to the Delaware River, to ascertain its distinctive features, essentially the same throughout, with its geological position still maintained. In New Jersey, I have likewise followed its equivalent strata across the state in the great series of variegated plastic clays, to the Raritan River, and again in their exposure on Staten Island, everywhere seemingly the same series of strata and of the same age. The position is a definite one, always along the line where the Jurassic must lie, if present.

Along the northern shore of Long Island, the same formation extends, and at many outcrops it may be seen with its characteristic features well displayed. I have recently examined these exposures at many points, and all tell the same story. At Montauk Point and on Gardiner's Island, I found apparently the same deposits, but with local variations that need not now be discussed.

Block Island, evidently once a part of Long Island, I have also examined. Its basal clays agree in most respects with the above representatives of the same horizon, as I have shown elsewhere.*

Gay Head.

By far the finest exhibition of the great formation in question may be seen on Martha's Vineyard, especially at Gay Head, which for a century has attracted the attention of geologists, who have tried in vain to solve its mysteries. My first visit to this classic region was in September last, and I know of no point on the Atlantic coast, from Nova Scotia to Florida, of more interest to geologists. The striking resemblance between the variegated cliffs at Gay Head, the Potomac hills in Maryland, and Como bluffs in Wyoming, will impress everyone who has seen them. That all three are of essentially the same geological age, I have good reason to believe. Two of them are certainly Jurassic, as demonstrated by typical vertebrate fossils, and I hope soon to prove that Gay Head, so similar in all other respects, also contains the same characteristic vertebrate fauna that marks the Jurassic,—the long missing formation on the Atlantic coast.

It has already been shown that the vertebrate fossils of the Potomac in Maryland prove its age there to be Jurassic, especially when taken in connection with the rich fauna of the Atlantosaurus beds of the West. In determining the age of the whole series, every aid that paleontology can render should be brought to bear upon the question, but a discrimination greater than has hitherto been shown is necessary to secure the best results.

In addition, then, to the evidence of vertebrate fossils as to the age of this eastern formation, the testimony of the invertebrates and plants should also be considered. The invertebrates known from these strata are few in number, but some of the mollusks among them point to the Jurassic age, as Whitfield has shown.† Nearly all, however, were estuary or fresh-water forms, which are now generally admitted to be of slight value as witnesses of geological changes.

Evidence of Fossil Plants.

Remains of plants are numerous, but usually fragmentary, and these have been collected at many localities, and studied by botanists of much experience in such investigations. The verdict they have rendered has not been a unanimous one, but is especially interesting, as it coincides at one point with the decisions some of their predecessors have rendered as to the age of other geological horizons in the succeeding formations of the West.

* This Journal, vol. ii, p. 295, October, and p. 375, November, 1896. In the second paper will be found an abstract of the more important literature.

† Monograph IX, U. S. Geol. Survey, p. 23, 1885.

The horizons I especially refer to are in the Dakota, Laramie, and Eocene, all essentially of lacustrine origin, and now well known. Fossil plants in good preservation have been collected in each of these in turn, and pronounced by eminent botanists to be Miocene. Other paleobotanists of equal eminence have reviewed the evidence and made the age somewhat older, but, as a rule, the conclusion reached made the deposits in question at least one period later than the animal remains indicated. To explain this discordance, it was in one case gravely asserted that a Cretaceous vertebrate fauna lived in the midst of a Tertiary flora. A larger knowledge of the facts has since led to revision of the first opinions on this point, and the Cretaceous age of both is now admitted.

It seems to me extremely probable that in the Potomac formation we again have an analogous case. The botanists have pronounced the plants Cretaceous, while the vertebrates are certainly Jurassic. Change the botanical scale one notch, as was done in the horizons above, and the flora and fauna agree, while the Jurassic formation, so long missing, is in its proper place on the Atlantic coast as it is in the West. The North American botanical timepiece was originally set by the European clock, which was one period too slow, as many facts now indicate. Sooner or later, an adjustment must be made.

Age of the Wealden.

To illustrate this, I may mention, as the latest change in the European time-standard, the Wealden formation, the Cretaceous age of which has long been considered a settled point. I had studied this formation at many localities in England and on the continent, as it contained a reptilian fauna similar to one I had found in the Rocky Mountains, and regarded as Jurassic. A further study of the Wealden reptiles caused me to question their Cretaceous age, and a comparison of these with allied forms from the Rocky Mountains led me to the conclusion that both series were Jurassic.

At the meeting of the British Association, at Ipswich, last year, I read a paper on European Dinosaurs, including two from the Wealden, and thus the question of their geological age came up for determination. The facts I presented, based mainly upon the reptilian fauna, strongly indicated the Jurassic age of the Wealden, and I urged a re-examination of the question by English geologists.* The subject has since been taken up by Smith Woodward, with special reference to the fossil fishes, on which he is high authority. In the Geological Magazine for February, 1896, he gives the main results of his investigation, which prove that the fishes, also, of the Wealden are of Jurassic types, thus placing the geological age of this formation beyond reasonable doubt.

* Report, British Association for the Advancement of Science, p. 688, 1895; and this Journal, vol. l, p. 412, November, 1895.

The same conclusion, based upon a review of the Wealden plants, has recently been reached by A. C. Seward, likewise an eminent authority, who states the case as follows: "The evidence of paleobotany certainly favors the inclusion of the Wealden rocks in the Jurassic series." *

Age of the Laramie.

The problem before us to-day has a strong family resemblance to another with which geologists were face to face twenty years ago; namely, the geological age of the great lignite series of the West. Then as now, the plants and the animal remains seemed to tell a different story, and I was thus led to investigate the question with considerable care. It may perhaps aid in solving the present problem if I repeat what I then said so far as it relates to the value of different kinds of fossils as evidence of geological age. In an address before the American Association for the Advancement of Science, in 1877,† I stated the case as follows:

"The boundary line between the Cretaceous and Tertiary in the region of the Rocky Mountains has been much in dispute during the last few years, mainly in consequence of the uncertain geological bearings of the fossil plants found near this horizon. The accompanying invertebrate fossils have thrown little light on the question, which is essentially whether the great Lignite series of the West is uppermost Cretaceous or lowest Eocene. The evidence of the numerous vertebrate remains is, in my judgment, decisive, and in favor of the former view.

Relative Importance of Fossils.

"This brings up an important point in paleontology, one to which my attention was drawn several years since; namely, the comparative value of different groups of fossils in marking geological time. In examining the subject with some care, I found that, for this purpose, plants, as their nature indicates, are most unsatisfactory witnesses; that invertebrate animals are much better; and that vertebrates afford the most reliable evidence of climatic and other geological changes. The subdivisions of the latter group, moreover, and in fact all forms of animal life, are of value in this respect, mainly according to the perfection of their organization or zoological rank. Fishes, for example, are but slightly affected by changes that would destroy reptiles or birds, and the higher mammals succumb under influences that the lower forms pass through in safety. The more special applications of this general law, and its value in geology, will readily suggest themselves."

* Catalogue British Museum, Wealden Flora, p. 290, 1895.

† This Journal, vol. xiv, p. 338–378, November, 1877.

In the statement I have quoted, I had no intention of reflecting in the slightest degree on the work of the conscientious paleobotanists who had endeavored to solve the problem with the best means at their command. I merely meant to suggest that the means then at their command were not adequate to the solution.

It so happened that the most renowned of European botanists, Sir Joseph Hooker, was then in this country, and to him I personally submitted the question as to the value of fossil plants as witnesses in determining the geological age of formations. The answer he made fully confirmed the conclusions I had stated in my address. Quoting from that, in his annual address as president of the Royal Society, he added his own views on the same question.* His words of caution should be borne in mind by all who use fossil plants in determining questions of geological age, and they are especially applicable to the problem now before us,—the age of the Potomac formation.

The scientific investigation of fossil plants is an important branch of botany, however fragmentary the specimens may be. To attempt to make out the age of formations by the use of such material is too often labor lost and must necessarily be so. As a faithful pupil of Goeppert, one of the fathers of fossil botany, I may perhaps be allowed to say this, especially as it was from his instruction that I first learned to doubt the value of fossil plants as indices of the past history of the world. Such specimens may indeed aid in marking the continuity of a particular stratum or horizon, but without the reinforcement of higher forms of life can do little to determine the age.

The paleobotanists have certainly failed repeatedly in the past, in attempting to define geological horizons by fossil plants alone. Although they have this record as a guide, some of them are still using the same methods, the same material, with the same confidence, that formerly misled their predecessors. In view of this, and of the great importance of the present question, is it too much to ask them to reconsider their verdict as to the age of the Potomac formation?

Were the fossil plants of the Potomac that have been pronounced Cretaceous unknown, the Jurassic age of this extensive series would have been accepted as a matter of course long ago. The strata themselves lie exactly in the position the Jurassic should occupy. They agree in physical characters more closely with the shallow fresh-water shales and sandstones of the Trias below, than with the deep-sea Cretaceous beds above. Still more important, the animal remains taken together, invertebrates and vertebrates, indicate one fauna, the Jurassic. Under these circumstances, the plants alone cannot finally decide the age.

* Proceedings Royal Society of London, vol. xxvi, pp. 441, 443, 1877.

Position of Jurassic Strata.

In the geological section, figure 1, on page 434, the relative position of the Jurassic deposits of the West is designated, and this will hold good for all the strata of that age in known localities on both flanks of the Rocky Mountains. In the East, the position of the deposits here regarded as Jurassic is equally definite, and corresponds strictly to that of the western horizon in its most essential features. A reference to the section in figure 2, below, will make this clear. This typical section is based on one by G. H. Cook, in the Geology of New Jersey,* and represents the successive Mesozoic and more recent formations, from New Brunswick, New Jersey, on a line southeast, through Lower Squankum to the Atlantic. The relative proportions and inclination of the various divisions cannot, of course, be given accurately in so small a figure. The distance represented by this section is about forty miles.

2.

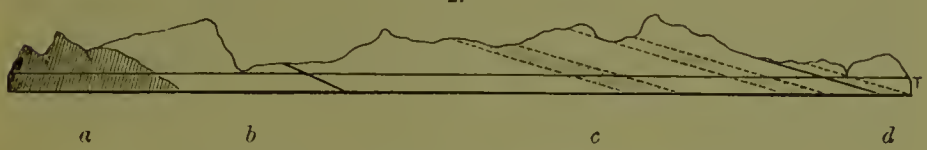

FIGURE 2.—Geological Section in New Jersey.

a, Triassic; *b*, Jurassic; *c*, Cretaceous; *d*, Tertiary; T, tide level.

In this section, the red Triassic shales and sandstones are shown on the left, highly inclined. Resting on their eroded surface are the well-known variegated plastic clays, also of fresh-water origin. These strata are nearly horizontal, having a slight inclination toward the ocean. The top of these peculiar clay beds is not clearly defined, but is marked by a change from lacustrine to marine conditions, which clearly indicate deposition in water of increasing depth, and finally deep-sea glauconite strata. These greensand deposits continued with some interruptions throughout the remaining Cretaceous time, and even into the early Tertiary, the third, or upper, marl bed being Eocene. Over these are strata of Miocene age, the Ammodon beds, and still more modern deposits form the shore of the Atlantic.

Atlantic Barriers.

The change from the fresh-water plastic clays of New Jersey to the marine beds containing greensand over them proves not only the breaking down of the eastern barrier which protected the former strata from the Atlantic, but a great subsidence also, since glauconite, as a rule, is only deposited in the deep, still waters of the ocean.

* Geological Map, Cretaceous Section 3, 1868.

The Miocene greensand surmounting the Gay Head clay cliffs on Martha's Vineyard also means the same thing, and a still greater lapse of time, as the whole Cretaceous and Eocene strata are here apparently absent. The present height of these Miocene strata indicates indirectly the minimum of elevation, the depth of the sea in which they were deposited being at present one of the unknown elements. It has been suggested by some geologists that the eastern barrier was composed of granitic rocks, and thus furnished the materials for the New Jersey and other clays.* Many known facts support this view.

The western, or inner, barrier of this great fresh-water border lake is still well marked. In the New England region, the present rock-bound coast line indicates its approximate position, and retains in its bays and inlets remnants of the deposits then laid down. Away from the coast, I know of only a single locality that seems to have preserved these beds, and that is near Brandon, Vermont. This basin I explored long ago, and if my memory serves me rightly, I saw there the typical clays, lignites, and iron ores, that mark the horizon now under consideration. South of New England, the inner barrier is equally well defined by the Triassic and older rocks to the Potomac River, but beyond that point I have not carefully examined it.

Physical Characters of the Jurassic.

The strong resemblance in their physical characters between the fresh-water deposits here regarded as Jurassic and those long known to be such in the Rocky Mountain region is largely dependent on the materials of which they are formed, and the conditions under which they were deposited. The close correspondence in this respect between the beds of the two regions should have some value in estimating their age.

The most striking feature in these deposits is the variety of colors in the plastic clays. Brilliant red, green, and yellow tints are especially prominent, yet the white and black shades are equally noticeable. While these colors are often seen in great masses, marking definite strata in fresh exposures, they blend one with another from the effects of weathering, where the original colors wash over each other. In the Rocky Mountain region, the brilliant hues of the Jurassic strata may be seen for miles on the face of the high bluffs. This is especially remarkable in the cliffs at Como, Wyoming, a representation of which is before you. Still more brilliant effects may be seen in the canyons on the west side of the Green River, in Eastern Utah.

East of the Rocky Mountains, the same color scheme is well illustrated around the Black Hills, in South Dakota. Again in the foot-hills west of Denver, near Morrison, Colorado, a

* Geology of New Jersey, Report on Clays, p. 30, 1878.

similar exhibition is to be seen, as represented in the second drawing. This is repeated on a much larger scale further south, near Cañon City, Colorado, as likewise shown in still another sketch, but none of these colored drawings does justice to the natural scenery.

On the Atlantic coast, the same combination of colors, although less brilliant, may be seen in the Potomac outcrops in Maryland, now proved by vertebrate fossils to be likewise Jurassic. Further north, the reds predominate in this horizon across Delaware and Pennsylvania, but in the plastic clays of New Jersey, the strong distinct colors, usually in horizontal bands, are dominant. On Staten Island and at various outcrops along the northern shore of Long Island, as well as on Block Island, the same horizon is distinctly marked by variegated patches, while still further east, at Gay Head, on Martha's Vineyard, the most startling color display of the whole Atlantic coast forms a flaming beacon that mariners and geologists alike have for a century held in high esteem. I know of no other horizon of equal extent so readily distinguished from all others by its physical features.

Early Investigations.

In the early days of American geology, the pioneers here, as in other branches of science, attempted to refer everything to European standards. In this way, strata of various ages, as we now know, were called by European names, and were supposed to represent equivalents. In this general way, the terms Lias, Oolite, etc., were applied to strata on the Atlantic coast. It was soon found, however, by the actual workers in the field, that our geological sequence had only a general correspondence with that of Europe or of other parts of the world, yet some geologists still endeavor to harmonize the time tables, but with only moderate success. It is, however, now becoming known, that this continent had its own law of development, and that its fauna and flora must be studied by themselves to disclose their full significance. The time ratios of America certainly do not coincide with those of Europe. The long periods of Mesozoic time represented in Europe by great deposition of many series of strata were marked here by other means as well. The rich fauna and flora that then lived here do not have their exact counterparts elsewhere.

The apparent absence on the Atlantic coast of the Jurassic as known in Europe naturally led the early geologists to seek its equivalent strata. The first supposed identification seems to have been recorded by W. B. Rogers, who called the eastern Virginia coal beds Oolitic.* These beds are now regarded as Triassic.

* Transactions Association American Geologists and Naturalists, vol. i, p. 300, 1843.

This eminent geologist also referred to the Jurassic certain silicious, argillaceous, and pebbly beds in Virginia and further north, as possibly "a passage-group analogous to the Wealden of British geology."* P. T. Tyson in 1860 referred the Maryland clays to the Cretaceous, and later to the Jurassic.†

Long before this, in 1835, H. D. Rogers, in his sketch of the geology of North America, clearly recognized what is here regarded as Jurassic as pertaining to one great formation. He described this as extending along the tide water plain of the Atlantic, from the Carolinas through Virginia, Maryland, Delaware, Pennsylvania, and New Jersey, and also as continuing on through Long Island to Martha's Vineyard and Nantucket. He gave it the name of "Ancient Alluvium," but included in it the plastic clay formation and part of the Gay Head deposits, the latter of which he considered Cretaceous.‡

The next noteworthy description of the Jurassic as here defined was given by J. C. Booth in his report on the Geological Survey of Delaware, 1841. He described the variegated plastic clays of that state, and gave to them the name of "Red Clay Formation," which he regarded as belonging to the Upper Secondary. The more recent publications on this Atlantic Coast formation are well known, and need not be cited here.

Among the early explorers who contributed to our knowledge of the Jurassic of the Rocky Mountains and Pacific coast region were J. Marcou, in New Mexico, 1853; C. King, in California, 1863; and, in the same state, W. Gabb, 1864, and F. B. Meek, 1865.

The earliest discovery of the Jurassic in the Arctic region of this country was by Sir E. Belcher, in 1852, who found remains of *Ichthyosaurus* on Exmouth Island. The latest information in regard to the Jurassic comes also from the Arctic region, where Nansen has found this formation containing many fossils, near Franz Joseph Land.

Jura-Trias.

The term Jura-Trias now in use is in reality a confession of ignorance, excusable, perhaps, a quarter of a century ago, but unpardonable now in those whose duty it is to map or define the formations of this country. Yet this term is still sometimes used for so clean-cut a Triassic horizon as the Connecticut River sandstone. It is true that in early days of New England geology, this formation was in part referred to the Jurassic, but at the present time no one at all familiar with the evidence of the abundant vertebrate life found in it could make such a mistake. This is equally true of the southern extension of the same formation along the Atlantic coast, where it is everywhere quite distinct from the Jurassic. In the West, the dividing line is less marked in some regions, but I believe that even there careful explorations alone are required to separate these two allied formations.

* Proceedings Boston Society, vol. xviii, pp. 104, 105, 1875.

† 1st Report State Chemist, Maryland, p. 41, 1860; 2d Report, p. 54, 1862.

‡ Report British Association, Edinburgh Meeting, pp. 1–66, 1835.

Vertebrate Fauna of the Jurassic.

The Jurassic age of the Atlantosaurus beds of the West has now been demonstrated beyond question by the presence of a rich fauna of mammals, birds, reptiles, and fishes. Among these, the *Sauropoda* were dominant, and the other Dinosaurs well represented.

In the Potomac beds of Maryland, the same Jurassic vertebrate fauna is present, as shown by the remains of five different orders of reptiles already discovered in them. Among the Dinosaurs are the *Sauropoda*, the *Theropoda*, and the *Predentata*, the first group represented by several genera and a great number of individuals. One of these genera is *Pleurocœlus*, which has also been found in the Jurassic of the West. Besides the Dinosaurs, characteristic remains of *Crocodilia* and *Testudinata* are not uncommon, and various Fishes have been found. The remains of these six groups already known are amply sufficient to determine the age of the formation, and still more important discoveries doubtless await careful exploration.

The discovery of vertebrate fossils further east is merely a question of systematic work. That they are there, all experience in this horizon clearly indicates. In 1870, I passed over miles of similar strata on the eastern flanks of the Uinta Mountains, with every man of my expedition on the lookout for fossils, prompted both by zeal for science and a special reward for the first specimen, but also on the alert for the hostile Ute Indians around us, yet not a fossil was seen. Ascending a few hundred feet, I found the sides of a narrow canyon full of fossils, vertebrate and invertebrate, all of Jurassic forms. The stratum once established, the supposed barren clays soon furnished rich localities.

The similar Potomac clays were formerly pronounced quite destitute of animal remains by geologists of eminence, but hard work disclosed their treasures. The coast east of the Hudson has an abundance of the same strata, and offers still greater rewards to explorers. The Gay Head Indians are not hostile, but will be found active assistants in the good work, while holding fast to the traditions of their ancestors as to the volcanic origin of their narrow sea-scourged home.

Long Island Sound.

It is evident that we know the remnants only of the great formation we are now discussing, for the larger part of it has long since been swept away, and much of the remainder is covered up or obscured by later deposits. The origin of this formation is a great question in itself, while its gradual destruction offers still larger problems to the geologist. One of these only I have time now to touch upon, and that has special interest for me, as day by day from my study window I look across the Sound to Long Island.

The origin of Long Island Sound was doubtless largely dependent upon the soft Jurassic clays that once filled its bed. The barrier on the north was the rock-bound New England coast essentially as it is to-day. The outer barrier, now removed or beneath the ocean, was perhaps of less durable material, and, as the coast subsided, gradually succumbed to the assaults of Atlantic waves. The great terminal moraine at the close of the glacial period proved a second barrier, and the waters from the melting ice and the larger rivers sought an outlet to the sea, both east and west, and thus a channel was formed in the soft clays and sands that the strong ocean currents gradually enlarged to its present size.

Conclusion.

The problem now before us is the presence or absence, on the Atlantic coast, of strata of Jurassic age. The exact position where such deposits should be found, if present, is well known to all geologists familiar with our eastern border. The fresh-water Triassic beds below this position and the extensive marine Cretaceous above have long ago been carefully studied, and their exact limits defined.

For many hundred miles, along the line where the Jurassic should occur, there is a well-marked series of fresh-water clays and sands quite distinct from anything else on the coast, and the question is,—are these beds of Jurassic or Cretaceous age? The prevailing opinion hitherto has been strongly in favor of the latter, although this view separated two allied fresh-water formations, and still left out the great Jura, so well represented in other parts of the world, and especially in our own Rocky Mountain region.

How difficult it is to lay aside preconceived opinions, everyone knows. The long supposed absence of the Jurassic on the Atlantic coast seems to have blinded those who had the formation under their feet. The evidence to-day in favor of its presence, if not conclusive at every point, is vastly greater than the opposing testimony. Moreover, its acceptance explains at once a mystery of long standing,—why the records of Jurassic time were not preserved here in their true place.

To call this peculiar Atlantic formation Cretaceous in its various eastern outcrops, when the western expansion of the same characteristic deposits has been proved Jurassic, is certainly not scientific. To do this in the light of present testimony, including the animal remains, vertebrate and invertebrate, the unique structure and materials of the strata themselves, and especially their definite position where the Jura should be, is to violate the laws of evidence.

No geologist familiar with the facts will deny that the variegated Potomac clays in Maryland are continuous with those in Delaware, Pennsylvania, and New Jersey, and that the similar basal clays on Long Island, and the other islands to the eastward as far as Nantucket, are part and parcel of the same series. There is now positive proof that the southern end of this series is Jurassic, and it is certainly a fair conclusion that the remainder is of the same age. The burden of proof will rest upon those who hold to the contrary.

To place the strata in question in the Jurassic section of the Atlantic coast at once removes many difficulties that have hitherto perplexed students of the Mesozoic of this region. It completes the series, and shows in part, at least, what was done in deposition during that long interval between the end of Triassic and the beginning of Cretaceous time, when the great barrier was broken down, which, from the Devonian to the Cretaceous, shut out the waters of the Atlantic.

I must leave it to others with leisure at their command to work out the details of this well-marked series, and its relation to those above and below. I have no time to devote to the surface geology of this belt or to the earlier deposits of Tertiary time. Just now, the Mesozoic interests me most of all, especially its middle section, the Jurassic, as I believe great injustice has been done, since this has been denied its rightful place, and a name not its own stamped upon it.

In a later communication, I hope to discuss this question further, and especially the Jurassic beds south of the Potomac River.

Yale University, New Haven, Conn., November 16, 1896.